

FLIGHT CHARACTERISTICS OF AN X-15 MODEL AT LOW SPEEDS

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INTRODUCTION

A low-speed stability and control investigation has been made with a 1/7-scale free-flying model representing configuration number one of the X-15 airplane. The primary purpose of this investigation was to aid in the evaluation of one of the unique features of this airplane - the use of the horizontal tail for roll control. This type of roll control has appeared to be quite promising on the basis of various force-test investigations in the past. One of the questions that has arisen regarding the use of such a control is the effect of its large favorable yawing moments on dynamic lateral control characteristics. In this model-flight investigation, therefore, the lateral control characteristics of the X-15 configuration were studied with particular attention being given to the effect of the large favorable yawing moments.

DISCUSSION

As an introduction to the stability and control data to be presented, figure 1 shows the lift characteristics of the model which are quite unusual because of the large fairings. These data were obtained from low-speed force tests. The lift curve for the wing-body combination (without fairing) breaks at a fairly low angle of attack where the wing stalls. The addition of the fairing delays the break to a much higher angle of attack and nearly doubles the maximum lift coefficient. The addition of the horizontal tail causes a further increase in the maximum lift and delays the stall so that the lift of the complete model is still increasing at an angle of attack of 40° . At the higher angles of attack, the wing is producing only about one-half the total lift.

It should be pointed out that, although data are shown up to an angle of attack of 40° in this and subsequent figures, the maximum angle of attack at which the airplane is expected to be operated in low-speed flight is less than 20° .

Shown in figure 2 are the roll control characteristics of the model determined from low-speed force tests. These data are for horizontal-tail deflections of $\pm 9^\circ$. The rolling effectiveness decreases with angle of attack, but some effectiveness is maintained even up to 40° . This

characteristic has been found in other investigations to be typical of the horizontal-tail roll control. It was found during the flight tests that the horizontal tail provided good roll control up to the highest angle of attack at which the model could be flown ($\alpha = 30^\circ$).

Shown in the lower part of the figure is the parameter C_n/C_l , the ratio of the yawing moment to the rolling moment produced by the roll control. These data show that the differentially deflected horizontal tail produces a favorable yawing moment that is about 0.7 as great as the rolling moment at low and moderate angles of attack. As the angle of attack increases, the yawing moment decreases and finally becomes unfavorable at about 32° . Most of the large yawing moment results from the fact that the horizontal tail has 15° negative dihedral so that when the tail is deflected differentially a rather large side force is produced. In other airplane configurations in which the horizontal tail has been used for roll control, most of the large favorable yawing moment has been produced by the loads induced on the vertical tail by the horizontal tail, but for the X-15 configuration this effect was quite small because of its particular tail arrangement.

It should be pointed out that the yawing-moment parameter C_n/C_l is only one of several factors that affect the yawing motions during rolling maneuvers. For example, at moderate and high angles of attack, large adverse yawing moments might be produced by the yawing moment due to rolling velocity C_{n_p} and by the product-of-inertia effect. Thus, the resultant yawing moment might actually be small or adverse even when the value of C_n/C_l is highly positive. It would be expected that the most critical condition for excessive favorable yawing moments would be the low-angle-of-attack range. The lowest angle of attack reached in the model flight tests was 8° and no objectionable yawing motions were produced by roll control at this angle of attack. In fact, the roll control appeared to be very good over the angle-of-attack range from 8° to 30° except that at the high angles of attack some adverse yawing was obtained. At angles of attack lower than 8° , the values of C_{n_p} and the product-of-inertia effect are likely to be quite small so that the resultant yawing moment would approximately correspond to the value of C_n/C_l shown in figure 2 at low angles of attack. In this event the large favorable yawing moment might well prove to be objectionable.

Figure 3 shows the test setup used to fly the model in the Langley full-scale tunnel. In this setup there is an overhead safety cable to prevent crashes of the model. Combined with this cable is another cable composed of plastic hoses which provide compressed air to nozzles in the model for thrust and wires which provide power for the control actuators. The thrust controller remotely controls the flow of air to the model by adjusting a valve located at the top of the entrance cone. The thrust

controller and the pitch pilot must coordinate their efforts in order to maintain steady flight. Another operator adjusts the safety cable so as to keep it slack during flight and takes up the slack to prevent the model from crashing if it goes out of control. A second pilot who controls the rolling and yawing motions of the model is located near the bottom of the exit cone. Motion-picture records of the flights are obtained with cameras located at the side of the test section and at the top and bottom of the exit cone.

Figure 4 shows the pitching-moment characteristics of the model with horizontal tail off and on. The pitching moment about the quarter chord of the mean aerodynamic chord is plotted against angle of attack. These data show that the model is longitudinally stable up to about an angle of attack of 30° and it then becomes unstable. The break in the curve is usually associated with pitch-up and occurs at about the maximum angle of attack at which the model could be flown. In the flight tests the model had a definite pitch-up tendency at angles of attack of about 30° which resulted in the model reaching very high angles of attack beyond the stall if no control was applied to prevent it. However, the pilot could usually prevent a pitch-up by proper use of control, since the pitching motion was fairly slow and the longitudinal control was powerful.

Shown in figure 5 are the lateral stability characteristics as given by the directional-stability parameter $C_{n\beta}$ and the effective-dihedral parameter $C_{l\beta}$ plotted against angle of attack for the complete model and for the model with upper vertical tail off. The directional stability of the complete model is high through the lower angle-of-attack range and then falls off rapidly to become negative at an angle of attack of about 30° . This can be attributed to both an increase in the destabilizing moment of the wing-fuselage combination and to a decrease in the contribution of the upper vertical tail. It is shown on the lower part of the figure that $C_{l\beta}$ also becomes zero at an angle of attack of about 30° . Static characteristics such as these in which $C_{n\beta}$ and $C_{l\beta}$ both become zero usually give rise to a directional divergence. As the model approached an angle of attack of 30° in the flight tests, there was some evidence of the decreasing directional stability and the model finally diverged despite attempts by the pilot to prevent it.

Figure 6 shows the damping in roll and the damping in yaw about the body axes obtained from rotary-oscillation tests. The variations of these derivatives with angle of attack are shown for two values of the reduced-frequency parameter ($k = 0.06$ and 0.16). The data show that the values of damping in roll and yaw are both essentially constant up to an angle of attack of about 20° and then the values of both derivatives increase negatively with increasing angle of attack. At the lower angles of attack there is very little effect of frequency, but at the higher

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angles more damping is obtained with the lower frequencies. Large values of damping in roll and yaw such as these are considered very desirable for damping of the Dutch roll oscillation. The influence of these large values of the damping derivatives was evident in the flight tests where damping of the Dutch roll oscillation following a disturbance appeared to be almost deadbeat.

CONCLUDING REMARKS

In conclusion, it may be stated that on the basis of previous correlations of model and full-scale flight results the airplane will have generally good low-speed stability and control characteristics. The airplane should experience the pitch-up and directional divergence at an angle of attack somewhat higher than the 30° indicated by the model tests.

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LIFT CHARACTERISTICS

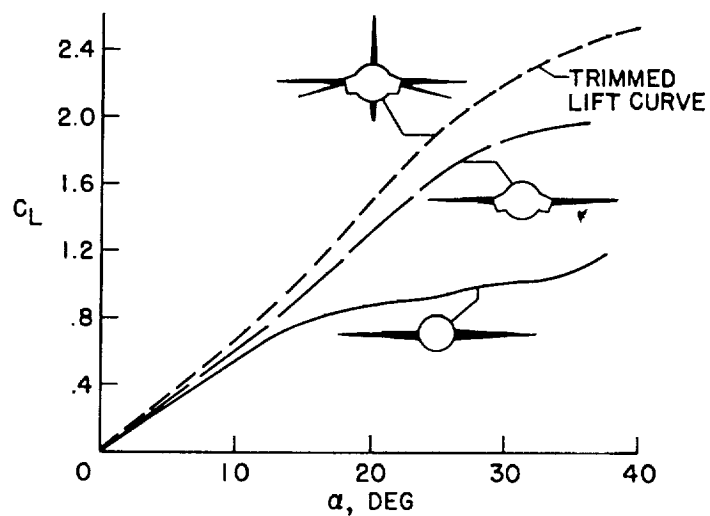


Figure 1

EFFECT OF ANGLE OF ATTACK ON ROLL CONTROL

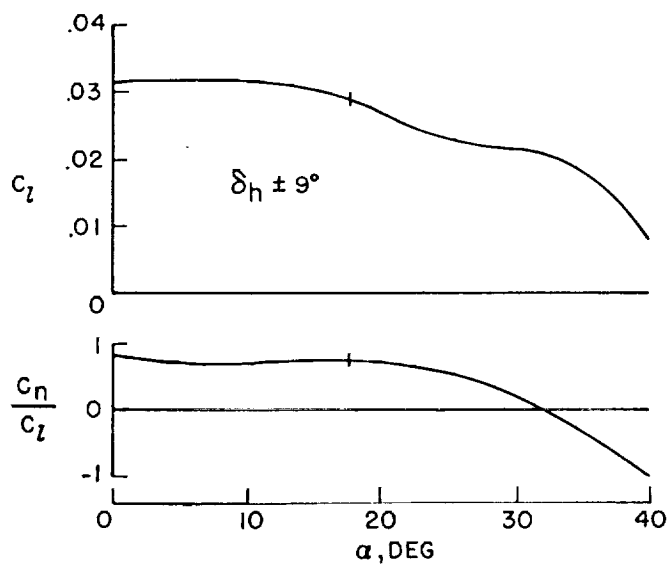


Figure 2

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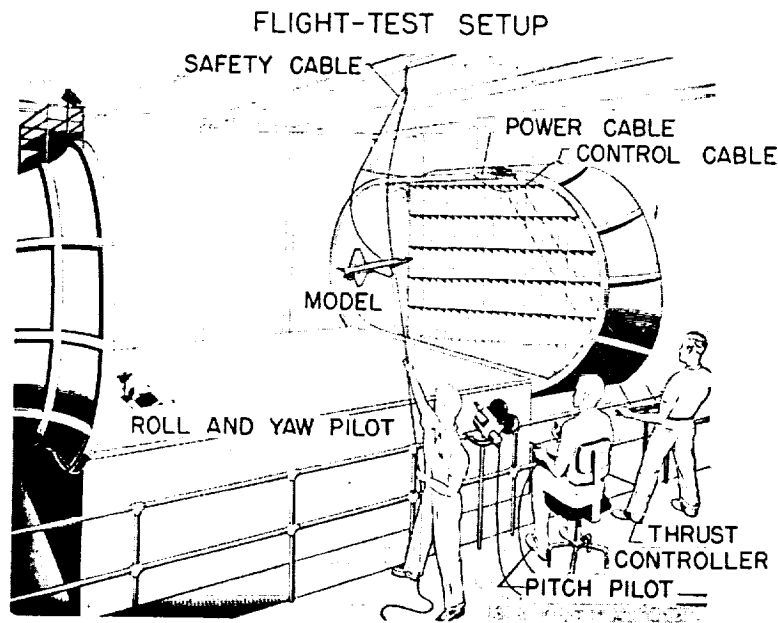


Figure 3

PITCHING-MOMENT CHARACTERISTICS

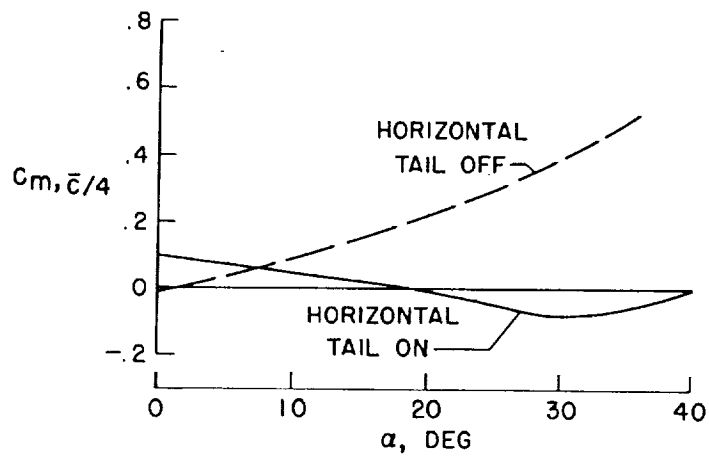


Figure 4

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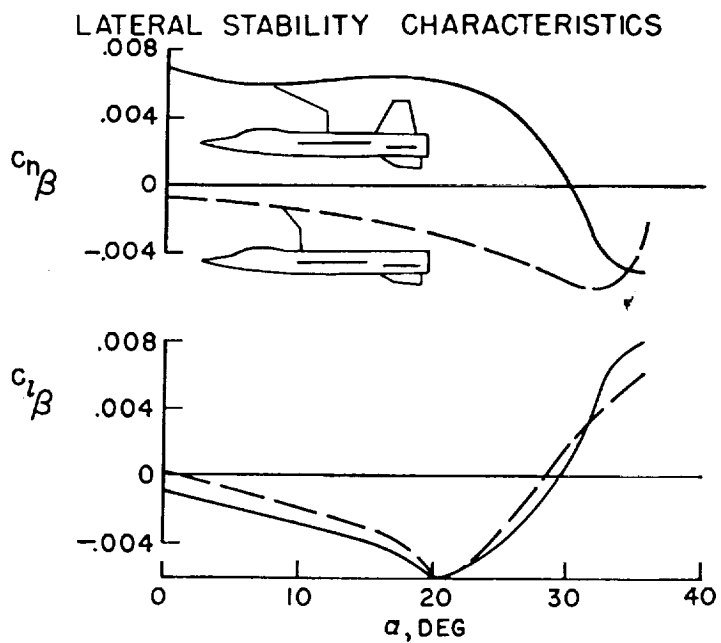


Figure 5

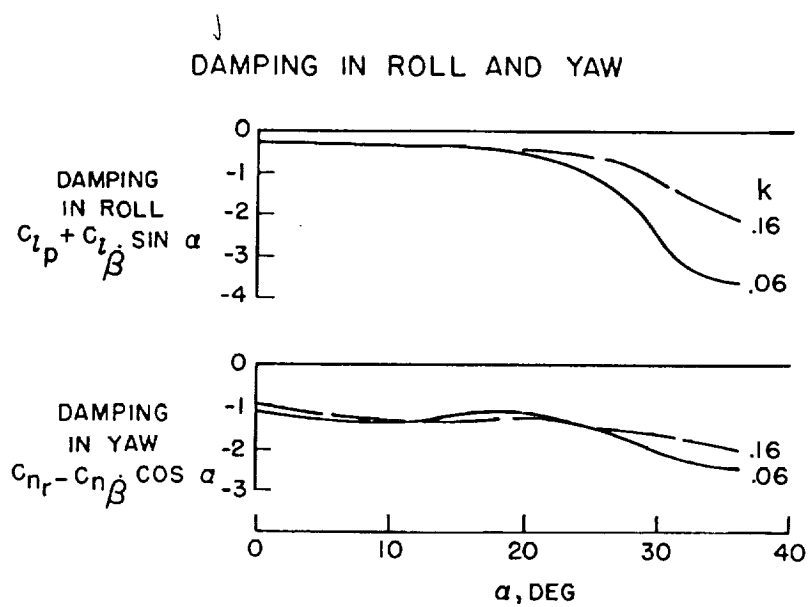


Figure 6